AND9842/D

Antenna Coil Prototype Design for Dual Interface RFID EEPROM Tag N24RFxx

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APPLICATION NOTE

The N24RFxxE is a RFID/NFC tag with xx indicating the equivalent memory size of 04/16/64 Kb EEPROM device offering both contactless and contact interface with Energy Harvesting capability.

This document describes and demonstrates different types of antenna design for a NFC application with RF contactless interface operating at 13.56 MHz.

The picture below shows the pins AN_1 and AN_2 of the N24RFxxE input pins used to connect the device to an external antenna in terms of inductor coil. The coil is used to power and access the device through the ISO 15693 RF protocols. The internal tuning capacitor or the input capacitance of the device varies from 26 pF to 30 pF by applying AC voltage from 1 Vpp to 2 Vpp verified with a LCR meter. The inductivity of L_{Ant} need to be selected in conjunction with input capacity of the device to get the resonance frequency at 13.56 MHz according to the eq.1.

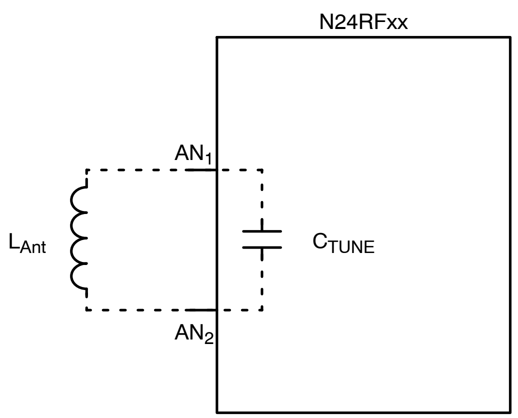


Figure 1. Antenna

$$fres = \frac{1}{2\pi\sqrt{L_{ANT}\,C_{TUNE}}} \qquad \text{(eq. 1)}$$

The picture below shows the impedance of a RLC resonance circuit. At the resonance frequency, the reactance compensate to each other, below the resonance frequency capacitive and above inductive.

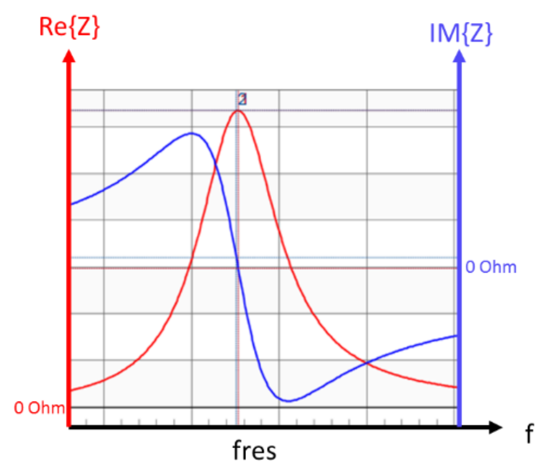


Figure 2. Impedance of a RLC Resonance Circuitry

Antenna Design Flow

Most commonly used antenna type for the RFID and NFC applications on the market is planar single layer coil antenna on the PCB due to easy and flexible design capability of the antenna size and low cost against external SMT/SMD inductors. The inductivity of a planar single layer coils depends on the geometrical data of the coil outline size, space, number or turns and width of the trace on the PCB. The online tool [2] provides first approximation to get the target inductivity based on the geometrical data of the coil.

As a start point for an antenna coil design the following steps need to be considered

1. Determine the input chip capacitance and design the inductivity to get the operating resonance frequency at 13.56 MHz
   a. The internal chip capacitance of the N24RFxx varies in the range from 26 pF to 30 pF
   b. The required inductivity using eq.1 targeted in the range of 4.7 μH to 5.1 μH
2. Determine the allowable antenna size and types based on the requirement of the NFC tag applications
   a. Surface−mount inductor
   b. Rectangular, circular or other shape of planar inductors on PCB or Flexboard
      i. Determine size, number of turns, track width, spacing to get the required inductivity

Simulation of PCB Coil Antenna Inductivity

To calculate the rectangular/circular planar inductivity the online tool on the webpage [2] can be used or a circuit simulator [3] to simulate a LC network to get required resonance frequency. [2] provides already a ready to use single layer rectangular or circular component based on the geometrical parameters. The picture below shows a credit sized antenna coil with 6 turns designed based on a LC resonance circuit simulation.

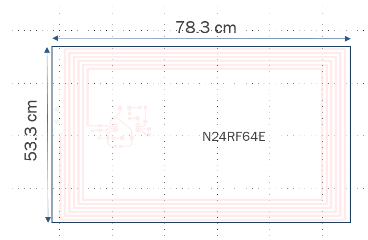


Figure 3. Credit Sized Antenna Coil

Figure 4. Resonance Circuit Simulation

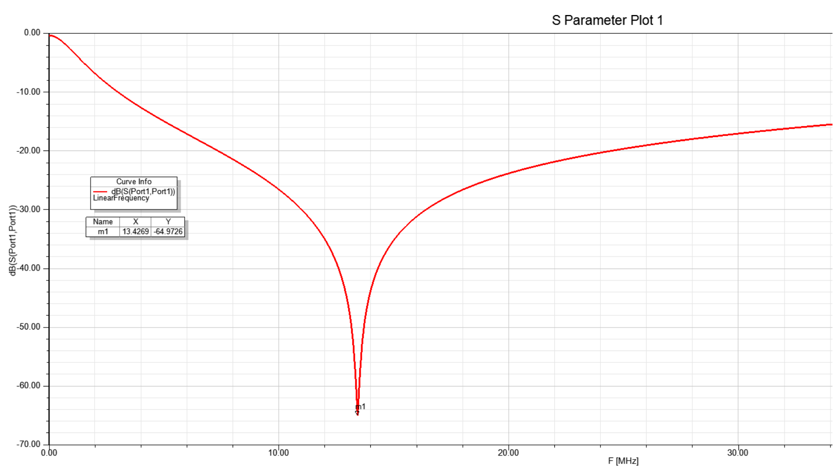


Figure 5. Resonance Frequency Simulation

The Figure 6 shows a double layer antenna simulation which shows the inductivity of 4.56 μH and the resonance frequency at ~13.6 MHz.

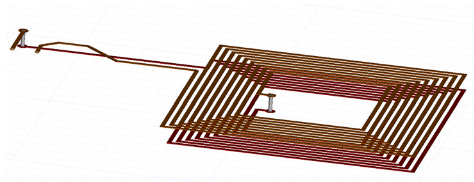


Figure 6. Double Layer Antenna Simulation with Ansys HFSS

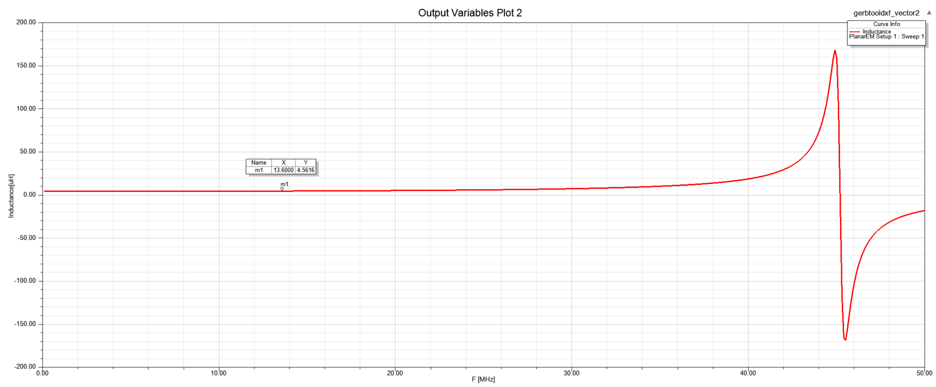


Figure 7. Inductivity of the Double Layer NFC Antenna with L = 4.56 μH @ 13.6 MHz

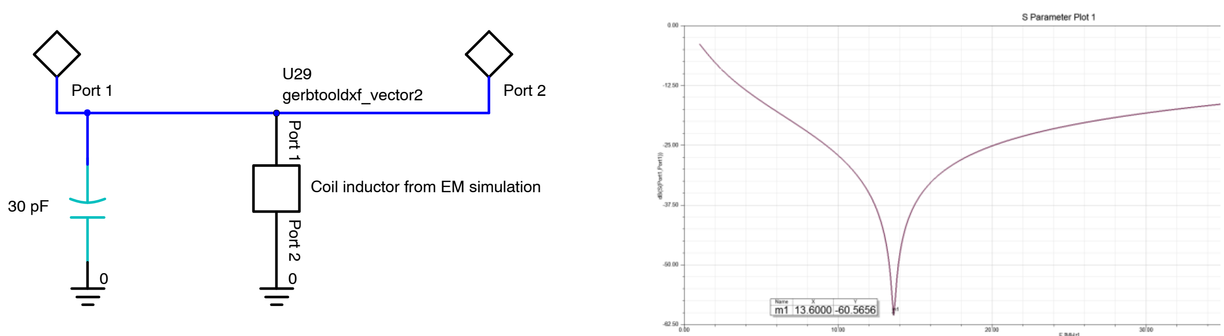


Figure 8. Double Layer Coil Inductor and Resonance Frequency Simulation

NFC Evaluation Board Prototypes with Different Antenna Concepts

The pictures below shows different layout of the N24RFxx evaluation boards with different antenna types SMT coil, double layer PCB antenna and circular flexboard antenna.

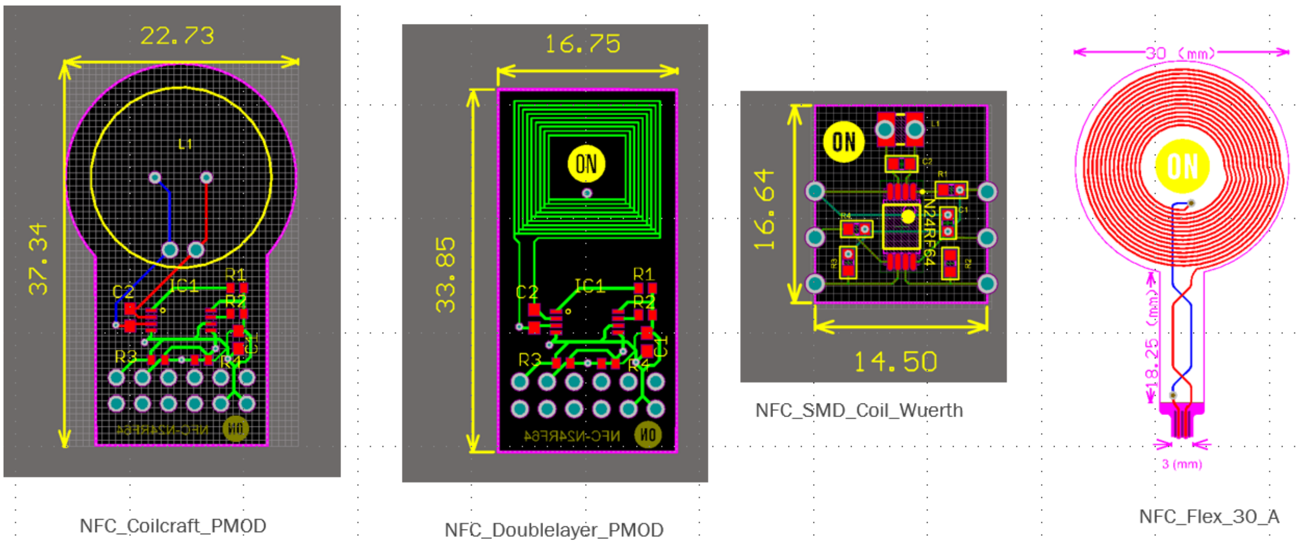
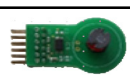
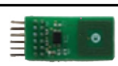
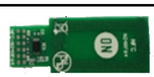


Figure 9. NFC Evaluation Boards

The final evaluation boards have been tested with a Samsung Galaxy Smartphone using a NFC android app to verify the communication distances. The evaluation board with the small sized SMD coil needs to be located as close to the smartphone as possible in order to read the N24RFxx UID.

The other boards with SMT coil and PCB antennas showed the reading distance up to 1 cm.

Table 1.

	Antenna Type	Communication Range	Board Size	Comment
	Wuerth SMD coil	~0.1 cm	14.5 x 16.6 mm	Smallest antenna size but poor communication range
	Coilcraft SMT coil	~1 cm	22.73 x 37.3 mm	PMOD interface I^2C
	PCB double layer	~1 cm	16.75 x 33 x 85 mm	PMOD interface I^2C
	PCB rectangular	~1 cm	60 x 20 mm	Evaluation Board
	Circular	~1 cm	30 mm diameter	Flex pcb antenna

The picture below shows the NFC shield attached to the IDK IoT baseboard via PMOD interface for the I^2C communication. The memory of the EEPROM can be written and read either via I^2C or RF interface via the antenna coil and demonstrates an IoT application using double interface EEPROM capability on the NFC shield.

Figure 10. NFC Shield Attached to the IDK Baseboard

Design and Development of Credit Sized NFC Evaluation Board

This chapter describes a simple NFC application board with a rectangular antenna coil in the size of a credit card.

The outline size of the antenna coil is selected in the range of a standard credit size about ~7.7 mm x 5.2 mm.

With the required size, the number of turns, width and space of the trace need to be selected to get the required inductivity in the range of 4.6 μH to 5.2 μH.

Simulating with [3] outputs the geometrical data of the rectangular coil characteristics:

Outline coil size 7.5 x 5 cm, number of turns = 6, width and space of the trace = 0.6 cm an inductivity value about 5.1 μH. On the Vout pin [1] a LED has been connected to demonstrate the Energy Harvesting capability of the device. Once a NFC reader or smartphone with NFC capability is put near the antenna coil, the LED will light up with the supplied voltage on the Vout pin.

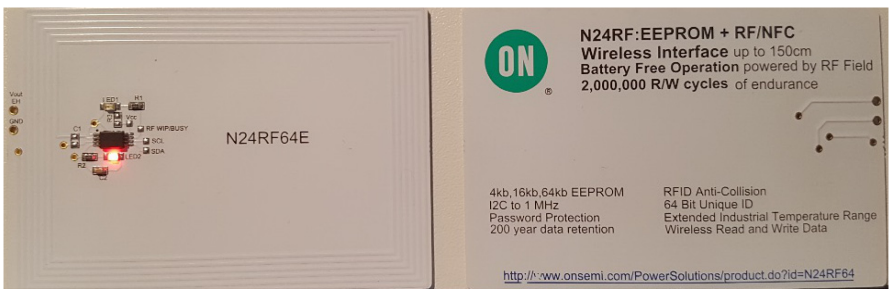


Figure 11. N24RF64E with Energy Harvesting

The reading distance depends on the NFC Reader and its magnetic field to power up a NFC device in the proximity. According to Ampere's law current flowing in a conductor produces a magnetic field around the conductor. The magnetic field of a reader antenna, in most cases circular or rectangular loop antenna depends on the geometrical structure, current flowing through the conductor, number of turns and the distance d from the antenna whereby the magnetic field strength decays approximately with $\sim 1/d^3$.

To demonstrate the reading distance of the credit sized antenna following measurement has been carried out.

The operating magnetic field of N24RFxxE is specified according [1] from 150 to 5000 mA/m.

Two readers were used, a Samsung Galaxy S7 smartphone and a CPR30 standalone desktop reader from Feig. The Feig CPR30 has greater transmission output power than the smartphone at 100mW.

From the measurement with a spectrum analyzer, the magnetic field, generated by the smartphone reader, at 1 cm is about 177 mA/m with max reading distance about 2 cm whereas the magnetic field of the standalone reader CPR30 is about 460 mA/m with maximum reading distance about 6 cm. This measurement shows the magnetic field strength of a standard smartphone and a standalone NFC reader with higher transmitting output power and higher reading distance.

Figure 12. Magnetic Field Measurement at the Distance 1cm

Table 2. READER TRANSMITTING POWER

	Pout	Magnetic Field at 1 cm	Reading distance of the Credit Sized Board
Feig CPR30	100 mW	~460 mA/m	6 cm
Samsung Galaxy S7	~ measured 15 mW peak	~177 mA/m	2 cm

Design and Development of a NFC Sticker Board

The following section describes the design of a sticker type inlay board with the following geometrical characteristics:

The specified outline size is about 40 x 40 mm, from the required outline size, the width and gap of the trace about 0.4 mm and the number of the turns 8 have been selected to get the required inductivity about 5 μH.

Antenna Quality Factor

The quality factor Q of a resonance circuits antenna is defined by the equation

$$Q = \frac{fres}{f_{BW}} \quad \text{(eq. 2)}$$

Whereby $f_{BW} = f_2 - f_1$ is the 3 dB bandwidth of the antenna.

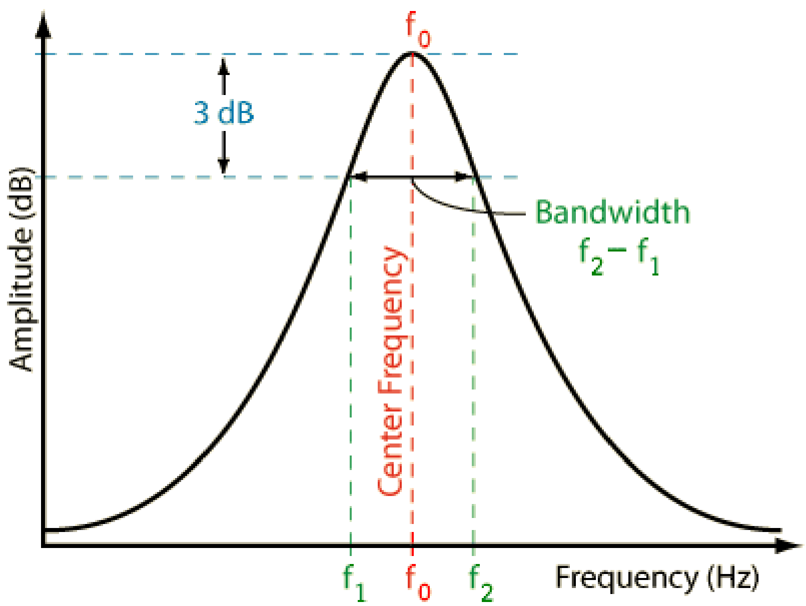


Figure 13. Quality Factor

A high quality factor means lower or narrower bandwidth but higher output power for the antenna and vice versa.

Therefore, by selecting the Q factor and resonance frequency, the bandwidth to cover the subcarriers on the one hand and the output power to meet the magnetic field strength from H_{min} = 150 mA < H_ISO < to H_{max} =5 A/m according to ISO 15693 [4] need to be considered during the antenna design.

ISO 15693 Compliant NFC Reader

Besides a smartphone with NFC capability, a standalone NFC reader supporting ISO 15693 standard can be taken to read and write the memory of N24RFxxE.

The two readers from Feig, listed in the table, have been verified to write and read the memory of N24RFxxE via RF interface with reading distance of about ~10 cm due to higher output power of the reader

Table 3.

Feig Reader Supporting ISO 15693	Demo Software	Pout
CPR30	CPRStart 2018	100 mW
ISC.MR102	ISOStart 2018	1.2 W

1. The CPR30 needs to use the latest firmware

Reference

[1] N24RF64E−D.PDF

[2] http://www.circuits.dk/calculator_planar_coil_inductor.htm

[3] Ansys HFSS

[4] ISO−15963−2 Part2: Radio frequency power and signal interface

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